Interaction Between Body Mass Index and Alcohol Intake in Relation to Blood Pressure in HAN and SHE Chinese

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Background: Blood pressure (BP) increases with body mass index (BMI) and excessive alcohol intake. Few epidemiologic studies explored the interaction between BMI and alcohol intake in relation to BP.

Methods: We randomly selected 10 villages with a mixed population of HAN and SHE Chinese in the JingNing County in Southeast China. We measured BP, anthropometric characteristics, and alcohol intake in 1688 participants. Our statistical methods included single and multiple linear and logistic regressions.

Results: HAN ($n = 520$) and SHE ($n = 1168$) had a similar sex and age distribution. SHE Chinese, compared with HAN, had a higher BP (128.0/79.7 *v* 121.5/76.9 mm Hg, $P < .001$), and more frequently reported alcohol intake (45.0% *v* 27.7%; $P < .001$), but showed lower BMI (22.2 *v* 22.5 kg/m^2; $P = .05$) and waist-to-hip ratio (0.83 *v* 0.87; $P < .001$). In SHE, but not HAN, there was a significant interaction ($P < .01$) between BMI and alcohol intake in relation to BP. In SHE with BMI < 25 kg/m^2, BP was significantly higher in drinkers than nondrinkers (129.4/80.2 *v* 124.2/77.4 mm Hg, $P < .001$), whereas among SHE with BMI ≥ 25 kg/m^2, BP was not associated with alcohol intake (134.3/84.9 *v* 136.8/85.7 mm Hg, $P > .41$). Accordingly, in SHE Chinese, the slope of BP associated with BMI was less steep ($P < .01$) in drinkers than nondrinkers.

Conclusions: Among SHE Chinese, alcohol intake and BMI interactively influenced BP. Further research is required to elucidate the underlying mechanism. Am J Hypertens 2006;19:448–453 © 2006 American Journal of Hypertension, Ltd.

Key Words: Blood pressure, body mass index, alcohol intake.

Numerous cross-sectional[1–4] and prospective studies[5,6] showed that heavy alcohol intake, particularly 42 g/d or more,[7] is a risk factor for the development of hypertension. Body mass index (BMI) is a major determinant of blood pressure (BP).[8–10] There is overwhelming evidence that lifestyle modifications, including weight reduction and alcohol abstinence reduce BP.[11,12] However, few epidemiologic studies explored the interaction between BMI and alcohol intake in relation to hypertension. Obesity and excessive drinking may increase BP through common pathways, such as activation of sympathetic nervous system or insulin resistance.[13–17] We hypothesize that obesity and alcohol intake may jointly influence BP. We recently conducted a BP survey in Southeast China in a mixed population of HAN and SHE Chinese, which is characterized by low BMI but a high proportion of drinkers. We therefore investigated the relationship between BP, BMI, and alcohol intake in these two Chinese ethnic groups.

Methods

Study Population

In 2002, we recruited subjects from 10 randomly selected villages of the JingNing County, a rural mountainous area approximately 300 miles south of Shanghai. We invited all

Received May 30, 2005. First decision August 23, 2005. Accepted August 24, 2005.

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The Ministry of Science and Technology, Beijing, China provided research grants (2001AA227061 and 2002BA711A05). The Bilateral Scientific and Technical Collaboration between Flanders and China (Ministry of the Flemish Community, Brussels, Belgium) supported Dr. Yan Li's postdoctoral fellowship in Belgium and travel of Dr. Jan A. Staessen to China (grant BIL02/10).

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0895-7061/06/$32.00
doi:10.1016/j.amjhyper.2005.08.014

Table 1. Characteristics of the participants

Characteristic	HAN (n = 520)	SHE (n = 1168)	P
Female, n (%)	278 (53.5)	648 (55.5)	.44
Age (y)	45.8 ± 15.2	44.5 ± 14.9	.09
Body mass index (kg/m^2)	22.5 ± 3.2	22.2 ± 2.9	.05
25–30 kg/m^2, n (%)	82 (15.8)	165 (14.1)	.38
≥30 kg/m^2, n (%)	16 (3.1)	16 (1.4)	.02
Waist-to-hip ratio	0.87 ± 0.07	0.83 ± 0.06	<.0001
Systolic blood pressure (mm Hg)	121.5 ± 19.5	128.0 ± 22.5	<.0001
Diastolic blood pressure (mm Hg)	76.9 ± 10.9	79.7 ± 12.3	<.0001
Pulse rate (beats/min)	72.2 ± 8.2	72.9 ± 8.1	.09
Hypertensive, n (%)	114 (21.9)	372 (31.9)	<.0001
On antihypertensive drugs, n (%)	24 (4.6)	75 (6.4)	.14
Alcohol intake ≥5 g/wk, n (%)	144 (27.7)	526 (45.0)	<.0001
Alcohol intake ≥300 g/wk, n (%)	87 (16.7)	325 (27.8)	<.0001
Smoker, n (%)	122 (23.5)	298 (25.5)	.37
Total cholesterol (mmol/L)	5.10 ± 1.01	4.86 ± 0.85	<.0001
HDL-cholesterol (mmol/L)	1.32 ± 0.27	1.40 ± 0.29	<.0001

Values are mean ± SD or number of subjects (%). P values are for the ethnic differences between HAN and SHE Chinese.

inhabitants with a minimum age of 12 years to take part in our study. The villagers were either HAN people, who constitute the predominant ethnicity of China or SHE, who immigrated into the study area around 1600 AD. Most people, irrespective of ethnicity, are farmers and share a similar lifestyle with the exception of alcohol intake, which is higher in SHE.[18]

The Ethics Committee of Shanghai Second Medical University approved the study protocol. All participants gave informed written consent. Of 2004 subjects (response rate 61.7%), 316 had missing information on BP or BMI (n = 90), lifestyle factors (n = 92), or serum lipids (n = 134). Compared to the 1688 individuals included in the present analyses, those with incomplete measurements were more likely (P < .01) to be of SHE ethnicity (69.2% *v* 84.1%), to be men (45.1% *v* 53.9%), and less likely to report alcohol intake (39.7% *v* 25.0%), but otherwise had similar (.11 < P < .69) characteristics, including age, BMI, and BP.

Data Collection

Five experienced observers set up a local examination center in each village. According to the guidelines of the British Hypertension Society,[19] they measured each participant's BP at the right arm with a conventional mercury sphygmomanometer after the subjects had rested for at least 5 min in the sitting position. Because obesity is rare among rural Chinese, we used standard cuffs that had an inflatable bladder with a length of 22 cm and a width of 12 cm. Three consecutive readings were averaged for analysis. Hypertension was defined as a BP of at least 140 mm Hg systolic or 90 mm Hg diastolic, or as the use of antihypertensive drugs. Body mass index was body weight in kilograms divided by the square of body height in meters. Using <25 kg/m^2, 25 to 30 kg/m^2, and ≥30 kg/m^2 as thresholds, we classified subjects in those with normal weight, overweight, and obese.

The observers administered a questionnaire to collect information on ethnicity, smoking habits, alcohol intake, and use of medications. The questionnaire provided information on the use of versus abstinence from alcohol and the frequency of the consumption of various types of alcoholic beverages during the past month. In the study area, beer is sold in bottles of 750 mL, whereas yellow aperitif, rice aperitif, and hard liquor are traded in units of 0.5 kg. We estimated that one unit of beer, aperitif, and liquor on average contained 30, 90, and 200 g of ethanol, respectively. From the type and quantity of the alcoholic beverages used, we computed alcohol consumption in grams per week to categorize participants in those not regularly drinking alcohol (<5 g/wk) and those consuming low to moderate or high quantities of alcohol (5 to 299, ≥300 g/wk, respectively).[7] We measured the concentration of total and HDL-cholesterol on fasting venous blood samples, using automated enzymatic methods.

Statistical Analysis

For database management and statistical analysis, we used SAS software, version 8.2 (SAS Institute, Cary, NC). Means and proportions were compared with the standard normal z-test and Fisher's exact test, respectively. We used analysis of covariance and multiple linear and logistic regressions to test associations of interest, while controlling for covariates.

Results

Characteristics of the Participants

The 520 HAN and 1168 SHE participants had a similar sex and age distribution (range, 12 to 91 years; Table 1). In both HAN and SHE, systolic and diastolic BP increased with age (data not shown). Compared to HAN, SHE had higher BP and included more hypertensive patients (Table

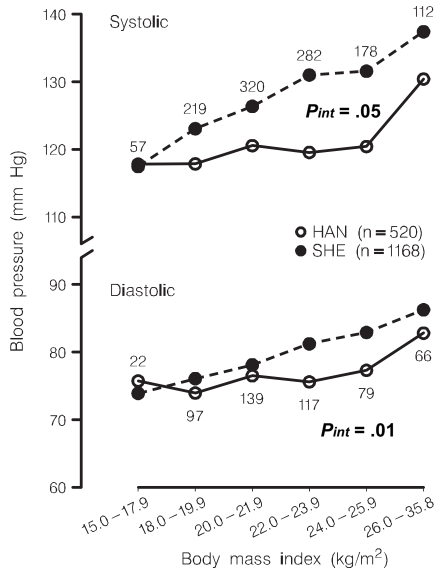

FIG. 1 Sex- and age-adjusted mean values of systolic and diastolic blood pressures by ethnicity and body mass index. The number of subjects per group is given alongside the symbols. *P* values for the interaction (*P*int) between body mass index (continuous variable) and ethnicity (0,1) were derived by multiple regression.

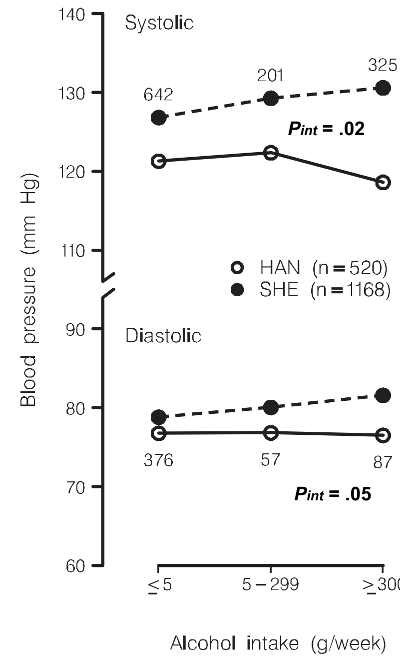

FIG. 2 Sex- and age-adjusted mean values of systolic and diastolic blood pressures by ethnicity and alcohol intake. The number of subjects per group is given alongside the symbols. *P* values for the interaction (*P*int) between alcohol intake (categorical variable) and ethnicity (0,1) were derived by multiple regression.

1). SHE were slightly leaner than HAN. Smoking was equally prevalent in the two ethnicities, whereas SHE men (63.3% *v* 42.2%) as well as SHE women (30.4% *v* 15.1%) more frequently reported alcohol intake than their HAN counterparts, particularly heavy drinking ($P < .001$). The proportions of heavy drinkers in SHE were 28.8% in normal weight subjects and 22.7% in obese and overweight subjects ($P = .11$). The corresponding percentages in HAN were 17.8% and 12.2%, respectively ($P = .23$). Irrespective of ethnicity, the serum concentration of HDL-cholesterol increased with higher alcohol intake ($P < .05$).

Association of BP With BMI

Among HAN and SHE, systolic and diastolic BPs consistently increased with BMI ($P < .001$; Fig. 1). However, the associations between BP and BMI were stronger in SHE than in HAN ($P \leq .05$ for the interaction between BMI and ethnicity). In multiple linear regression analyses adjusted for sex and age, each 3-kg/m^2 increment in BMI (approximately 1 SD) was associated with an increase in systolic/diastolic BP by 4.8/3.6 mm Hg in SHE, but only by 3.0/2.1 mm Hg in HAN. In logistic regression (Table 2), each 3-kg/m^2 increment in BMI increased the risk of hypertension by 81% in SHE and by 33% in HAN.

Association of BP With Alcohol Intake

Fig. 2 shows that among SHE ($P < .01$) but not HAN ($P > .25$), BP increased with alcohol intake. With adjustment for sex, age, and BMI, there were significant interactions ($P \leq .05$) between alcohol intake and ethnicity in relation to systolic and diastolic BP. We calculated the β estimates of BP associated with ethnicity before and after adjustment for alcohol intake. This analysis demonstrated that alcohol intake accounted for approximately 9% and 12% of the ethnic differences in systolic and diastolic BP, respectively. In logistic regression (Table 2), a daily alcohol consumption of 5 g or more was associated with a 41%

Table 2. Adjusted relative risk of hypertension in relation to sex, age, body mass index, and alcohol intake by ethnicity

	HAN (n = 520)		SHE (n = 1168)	
Characteristic	**Odds ratio (95% CI)**	***P***	**Odds ratio (95% CI)**	***P***
Sex, 0 = women; 1 = men	0.90 (0.55–1.48)	.69	0.90 (0.67–1.20)	.47
Age, +10 y	1.88 (1.60–2.20)	<.0001	1.76 (1.60–1.95)	<.0001
Body mass index (kg/m^2)	1.10 (1.03–1.18)	.007	1.22 (1.16–1.28)	<.0001
Alcohol intake, 0 = no; 1 = yes	0.76 (0.43–1.32)	.32	1.41 (1.05–1.87)	.02

Models included sex, age, body mass index, and alcohol intake as independent variables.

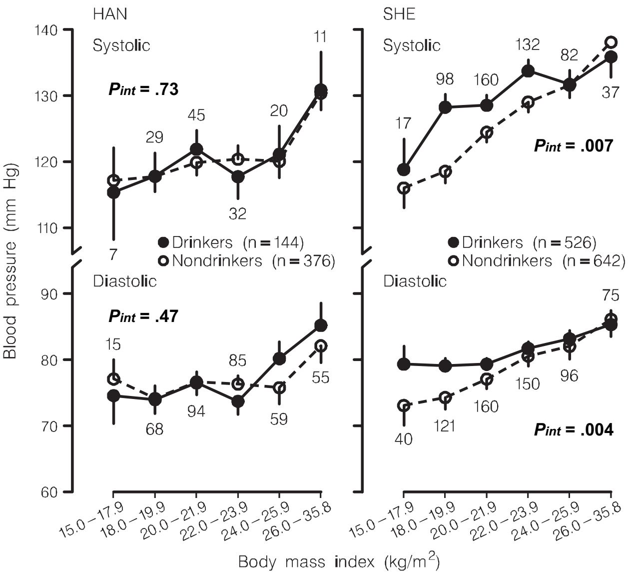

FIG. 3 Sex- and age-adjusted mean values of systolic and diastolic blood pressure by ethnicity, alcohol intake, and body mass index. Vertical line denotes SEs. The number of subjects per group is given alongside symbols. *P* values for the interaction (*P*int) between body mass index (continuous variable) and alcohol intake (0,1) were derived by multiple regression.

increase in the risk of hypertension in SHE, whereas the relative risk in HAN was smaller than unity and statistically insignificant.

Interaction Between BMI and Alcohol Intake

In further analyses, we studied the combined influences of BMI and alcohol intake on BP. In HAN, there was no significant interaction ($P > .47$) between alcohol intake and BMI in relation to BP, whereas in SHE ($P < .01$), BMI and alcohol intake jointly influenced BP (Fig. 3). In SHE with normal weight, BP was significantly higher in drinkers than nondrinkers (129.4/80.2 *v* 124.2/77.4 mm Hg; $P < .001$), whereas among overweight and obese SHE, BP was similar in drinkers and nondrinkers (134.3/84.9 *v* 136.8/85.7 mm Hg; $P > .41$). Accordingly, in SHE Chinese, the slope of BP associated with BMI was less steep in drinkers than nondrinkers. In SHE, each 3-kg/m^2 increment in BMI was associated with an increase in systolic/diastolic BP by 2.9 /2.2 mm Hg in drinkers and by 6.0/4.2 mm Hg in nondrinkers (Fig. 3).

Discussion

The key finding of our study was that in SHE Chinese BP was related to BMI, alcohol intake, and their interaction. In contrast, in HAN Chinese, who compared to SHE consumed less alcohol and were slightly obese, BMI and alcohol intake were independently associated with BP. In terms of the well-documented pressor effect of heavy alcohol intake and our observations, the drinking habit in SHE Chinese, to some extent, had contributed to their elevated BP and higher prevalence of hypertension.

SHE Chinese belong to the "PanHu" ethnic group, who about 400 years ago migrated across Southern China from west to east.[18] According to Chinese anthropologists, SHE did not master the technique of the long-term storage of grains. Over the centuries, they started brewing alcohol to make use of the surplus of their harvests. In line with published sociologic studies,[18] we noticed that across the age range alcohol intake was more frequent among SHE than HAN. Moreover, the proportion of heavy drinkers was also significantly higher in SHE than HAN in both sexes.

Alcohol intake and obesity are established risk factors in the pathogenesis of hypertension. However, only one other observational study[20] and one intervention trial[21] investigated the interaction between alcohol intake and BMI in relation to BP. Our observations that BP was higher with alcohol consumption in lean but not overweight and obese SHE Chinese are in keeping with the prospective study in Japanese male office workers.[20] Nakanishi and colleagues[20] found that during 9 years of follow-up the relative risk of hypertension in current drinkers versus nondrinkers was approximately twofold stronger among men with a BMI less than 24.2 kg/m^2 than among men with a higher BMI. In an 18-week randomized factorial intervention trial, Puddey and colleagues[21] studied the individual and combined effects of alcohol restriction and weight reduction on BP in 86 overweight and moderately drinking men. At 4 weeks of follow-up, alcohol restriction and weight reduction alone decreased systolic/diastolic BP from baseline by 4.8/3.3 and 5.4/4.2 mm Hg, respectively. The combined intervention revealed additive effects on BP with baseline-corrected decreases of 10.2 mm Hg systolic and 7.5 mm Hg diastolic. Accounting for the BP reductions in the control group, as shown in the trial report (~2/1 mm Hg), alcohol restriction alone had only a modest hypotensive effect. These results suggest that in overweight subjects, alcohol restriction and weight reduction are both required to have an appreciable BP reduction. Thus, this intervention study[21] also lends support for our observations, which suggest that abstinence from alcohol in overweight/obese SHE Chinese had little influence on BP.

The mechanism of the interaction between BMI and alcohol intake in relation to BP remains to be elucidated. A literature search did not reveal any evidence in favor of the hypothesis that the mass of body fat impacts on the metabolism of alcohol. However, several studies demonstrated that alcohol intake might influence the regulation of calorie intake[22] and thermogenesis.[23] One may argue that our observed interaction might be due to the higher proportion of heavy drinkers in lean subjects. However, our results do not support this hypothesis, because the proportion of heavy drinkers was similar across the levels of BMI in SHE as well as in HAN Chinese. We hypothesize that drinking alcohol and BMI may influence BP through common pathways, such as activation of sympathetic nervous system or insulin resistance. Obesity increases renal sodium reabsorption and impairs pressure natriuresis by activation of the renin-angiotensin and sympathetic nervous systems.[15,16] There is some evidence that alcohol also induces sympathetic activation.[13,14] Therefore, it is possible that obesity may offset or conceal the pressor effect of alcohol intake and vice versa. The sympathetic stimulation associated with alcohol intake or obesity may especially increase BP in lean persons or nondrinkers who in general have a lower sympathetic tone than obese subjects or drinkers.

The present study should be interpreted within the context of its limitations. First, self-reported alcohol consumption should be considered as soft information, because heavy drinkers tend to under-report their true intake. Second, we excluded from the present analysis 316 participants with incomplete data, which included more SHE men without drinking habits. However, this selection bias is unlikely to affect the validity of our findings, because these excluded subjects had similar BP as those included in the present analysis, irrespective of drinking habits. Third, unmeasured lifestyle characteristics, such as sodium intake might also have contributed to the present findings. However, in a subsample ($n = 108$) of the present population, the urinary sodium-to-creatinine ratio averaged 21.8 mmol/mmol creatinine and was similar in HAN and SHE. Fourth, we used only one cuff size for measuring BP of all individuals, and hence we might have overestimated the BP in frankly obese subjects. However, because the overall prevalence of obesity in our study was only 1.9%, the potential impact on our results is likely to be negligible. Finally, our study did not account for the type of alcoholic beverage or the pattern of alcohol intake. Effects of drinking on BP are known to be more pronounced if the alcohol is taken separately from meals or if binge drinking occurs during weekends.[24,25] On the other hand, full adjustment for these unmeasured factors should strengthen rather than weaken the present association between BP and alcohol intake. Furthermore, two observations support the validity of our epidemiologic results. As expected, we found a strong positive association between the serum concentration of HDL-cholesterol and the amount of alcohol consumed across ethnicities. Second, the mean values of BMI and the prevalence of overweight and obesity in the JingNing villagers were in close agreement with those contemporarily reported in other rural Chinese populations.[26]

In conclusion, among SHE Chinese, alcohol intake and BMI interactively influenced BP, whereas among HAN BMI and alcohol intake were independently associated with BP. To what extent the interaction between BMI and alcohol intake in relation to BP is dependent on genetic, environmental, or unmeasured lifestyle factors remains to be clarified. Further studies should also address the pathophysiologic pathways, which underlie the joint influences of BMI and alcohol intake on BP.

Acknowledgments

The JingNing Study would not have been possible without the voluntary collaboration of the participants and the help of the local public health authorities. The authors gratefully acknowledge the expert assistance of Shou-Yu Mao, Wei-Zhong Zhang, and Huai-Fa Zhou (Shanghai Institute of Hypertension, Shanghai, China).

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